Case study of reactivation of two wastewater treatment plants with upgraded processes for operational and quality improvements

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Highlights:

- Two WWTPs consisting of Sequential Batch Reactors with aerobic digestion were out of operation and required extensive retrofitting
- Upgrade of the units involved installing fine bubble diffuser mesh and blowers, on-site sludge dewatering, automation, construction of operational facilities
- Upon completion of retrofit works the WWTPs' performance was very high, achieving removal efficiencies of >90% for all parameters
- DBO5≤23 mg/L, MBAS≤0.8mg/L, TSS≤12 mg/L and N-NH4≤9.7 mg/L were achieved in all analyses of treated sewage

Keywords: wastewater treatment; sequential batch reactor ; upgrading wastewater treatment plant

INTRODUCTION

A challenge for the universalization of sanitation services is the cost of operation and maintenance of WasteWater Treatment Plants (WWTP). This challenge is particularly pronounced in developing countries, where is not uncommon to exist shortage of essential goods and materials needed to effectively run WWTPs (Garayo Junior et al., 2022). This issue becomes even more critical when it comes to small units in small municipalities within these developing countries. In Brazil, this problem is evident through the existence of WWTP that have not been operated for many years, having been abandoned either without ever starting operation or after operating for a short period of time.

Taking charge of sanitation systems in multiple municipalities, the water supply and sanitation company which conducted this study identified two WWTP that were not operating. The company then launched an intervention plan to reactivate these units, also considering an upgrade of the original treatment processes aiming at: a) improving the quality of treated effluent (treated sewage), b) achieving greater reliability and consistency in meeting quality targets required by environmental regulation and c) reducing operational costs in treatment. The objective of this case study is to present and discuss the original situation and its limitations, the conception of planned interventions and the operational outcomes following the completion of the WWTPs' upgrading.

METHODOLOGY

The present work followed a model of methodological procedure for case studies in the sanitation field, which is based on a descriptive research using data collected in a real situation, thus constituting primary data. The authors developed the work aiming to describe, explore and explain the data and outcomes (Almeida et al. 2023; Silva et al. 2023). The methodological procedure was divided into three stages:

1) describing the situation of the WWTPs as encountered by the sanitation company, including information from the original projects and an analysis of the limitations of the original design in light of processes and compliance with environmental legislation; 2) describing the proposed project modifications and its rationale 3) presenting the WWTP's performance through operational results. WWTPs' performance was measured in terms of efficiency in removing five-day Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Settleable Solids (SS), Total Suspended Solids (TSS), total ammoniacal nitrogen ($N\text{-}NH_4$) and surfactants (measured as Methylene Blue Active Substances (MBAS)). These parameters were monitored by an accredited external laboratory, following standard analysis methodologies (APHA, 2012). Composite sampling of both raw and treated sewage was conducted and efficiency (%) was calculated as the value of the parameter in raw sewage minus value in treated sewage, divided by the value of raw sewage.

RESULTS AND CONCLUSIONS

The original design of the two WWTPs included preliminary treatment (coarse screening and sand removal) and secondary treatment with Sequential Batch Reactor (SBR). WTP 1 had two parallel tank reactors designed to receive raw sewage alternately, with each reactor entering the filling/aeration cycle at a time. Conversely, WWTP 2 had only one reactor, resulting in raw sewage entering the reactor during settling and emptying cycles, with an expectation of significantly impacting treatment efficiency. Both WWTPs featured an aerobic digester compartment but lacked sludge dewatering units, flow measurement devices, and operational and chemical storage areas. Aeration was provided by surface aerators (two in the aeration tank and one in the digester) and manual operation controlled valve openings and closures during SBR cycles. The upgrade of the original design involved firstly increasing the air supply and improving air distribution by replacing surface aeration with fine bubble diffuser mesh in the aeration tanks (Figure 1) and adding blowers. These changes were included not only to improve treated effluent quality to meet BOD5 removal below 40 mg/L and MBAS below 2 mg/L, as mandated by the environmental regulatory agency, but also to ensure consistent and resilient performance to consistently achieve these targets. Upgrades also included adding a sludge dewatering project using geobag filters with pre-polymerization of sludge, adding ultrasonic water flow meter in a parshall flume and automating valve operations during SBR cycles. On-site dewatering was included to reduce operational costs by eliminating the need to transport liquid sludge for external dewatering. An equalization tank was added to WWTP1 to receive raw sewage (Figure 2) during settling and clarified effluent discharge cycles. Operational facilities like laboratories, chemical storage and operation rooms were also added to the WWTPs.


Figure 1: fine bubble diffuser mesh inside aeration tank


Figure 2: equalization tank installed

In the first month of operation, BOD5 and TSS levels were higher due to the time required for system stabilization. However, after 1 month, these parameters decreased and stabilized at consistently low levels. Results for WWTP 1 (Table 1) and WWTP 2 (Table 2) indicated very low values and very high removal efficiencies. Based on the reported outcomes, the WWTPs' reactivation and retrofitting project was considered a technical success.

		SS	BOD	COD	TSS	MBAS	N-NH4
Analysis 1	**Raw**	3.5	493	1504	368	4.1	81.97
	Treated	0.3	23	41	9	<0.1	2.73
	Efficiency	91%	95%	97%	98%	>99%	97%
Analysis 2	**Raw**	1.8	314	663	167.3	5.6	50.36
	Treated	<0.1	17	36	5.5	0.1	0.34
	Efficiency	>99%	95%	95%	97%	98%	99%
Analysis 3	**Raw**	3.5	331	807	224	2.6	40.1
	Treated	<0.1	16	40	1.5	0.2	1.05
	Efficiency	>99%	95%	95%	99%	92%	97%
Analysis 4	**Raw**	2.1	149	301	86	N.M.	41.97
	Treated	<0.1	3	<10	6.5	0.3	1.08
	Efficiency	>99%	98%	>99%	92%	-	97%
Analysis 5	**Raw**	2	414	886	390.9	5.1	49.94
	Treated	<0.1	16	32	5	0.2	0.43
	Efficiency	>99%	96%	96%	99%	96%	99%
Analysis 6	**Raw**	1	374	770	270	4.8	80.63
	Treated	<0.1	12	22	10.5	0.4	6.2
	Efficiency	>99%	97%	97%	96%	92%	92%
Analysis 7	**Raw**	1.9	453	915	282.3	N.M.	8.93
	Treated	<0.1	17	34	4	0.3	0.23
	Efficiency	>99%	96%	96%	99%	-	97%

Table 1 – Parameters of raw and treated sewage in WWTP 1.
N.M.: not measured (error in analysis)

		SS	BOD	COD	TSS	MBAS	N-NH4
Analysis 1	**Raw**	3	287	651	188.3	1.7	24.89
	Treated	<0,1	9	21	3	<0,1	0.59
	Efficiency	>99%	97%	97%	98%	>99%	98%
Analysis 2	**Raw**	2	203	442	135.6	3.7	40.83
	Treated	<0,1	10	17	10	0.2	4.65
	Efficiency	>99%	95%	96%	93%	95%	89%
Analysis 3	**Raw**	2	255	523	57	2.5	135.4
	Treated	<0,1	11	26	4	0.8	8.81
	Efficiency	>99%	96%	95%	93%	68%	93%
Analysis 4	**Raw**	8.5	403	1026	254	2.2	33.97
	Treated	<0.1	10	21	2.5	1	0.4
	Efficiency	>99%	98%	98%	99%	55%	99%
Analysis 5	**Raw**	3	346	550	154	6	28.36
	Treated	<0.1	3	<10	7	0.2	5.8
	Efficiency	>99%	99%	>99%	95%	97%	80%
Analysis 6	**Raw**	5	345	799	190	6.1	37.78
	Treated	<0.1	23	48	12	0.4	9.65
	Efficiency	>99%	93%	94%	94%	93%	74%
Analysis 7	**Raw**	15	998	1999	650	3.6	35.17
	Treated	<0.1	23	46	8	0.2	7.89
	Efficiency	>99%	98%	98%	99%	94%	78%

Table 2 – Parameters of raw and treated sewage in WWTP 2.

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